TITLE OF THE INVENTION

HEAD SWITCHING METHOD AND SYSTEM USING TRACK NUMBER MATCHING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 2002-73477, filed on November 25, 2002, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to hard disk drives, and more particularly, to a method of switching heads of a hard disk drive written using an off-line, servo track writing (STW) method.

2. Description of the Related Art

[0003] In general, hard disk drives include a plurality of disks and heads, wherein an individual disk is accessed by a corresponding head. Addresses used to access each disk are classified as head addresses, cylinder addresses, and sector addresses. As used herein, cylinders correspond to the tracks of a disk.

[0004] Servo tracks on conventional hard disk drives are written using an on-line STW method, where disks are first assembled on a drive and then servo data is recorded on the assembled disks. In other words, during a conventional hard disk drive manufacturing process, first, a disk assembly process is performed and then, servo tracks are written on the disks using a servo writing process. In the disk assembly process, a plurality of disks are assembled and fixed onto a drive. In the servo writing process, servo data, that is, track and sector addresses and servo address marks are recorded on the assembled disk by using a servo writer. U.S. Patent No. 5,796,542 describes a method and apparatus for simultaneous servowriting on a plurality of disks. Also, U.S. Patent No. 6,031,680 describes a method for self-servowriting.

[0005] In the on-line STW method, since all of the heads of a servo writer simultaneously perform servo writing, the track addresses of the individual disks on which corresponding heads are positioned are identical.

[0006] However, in recent hard disk drive manufacturing methods, the servo writing process is performed prior to the disk assembly process to achieve a simpler process. In other words, servo information is first individually recorded on each disk, and then the disks are assembled. This method is referred to as an off-line STW method.

[0007] In contrast with a hard disk drive having disks with information written using the on-line STW method, the disks of a hard disk drive having information written using the off-line STW method basically represent different track addresses when heads are positioned thereon. In other words, even when the disks are accurately assembled, there exists a deviation between disks due to an assembly tolerance. Thus, a deviation between heads is generated during assembly. Such a deviation may be in the order of magnitude of several hundreds of tracks.

[0008] The off-line STW method simplifies the process of writing information on a hard disk drive but degrades the performance of disks, that is, lengthens the time required to access the disks.

[0009] FIG. 1 illustrates a conventional disk accessing method. Referring to FIG. 1, upon recording, data is first recorded on an n-th track of an m-th disk and then on an n-th track of an (m+1)th disk. Next, data is recorded on the (n+1)th track of the (m+1)th disk and subsequently on the (n+1)th track of the m-th disk. In this example, since the m-th and (m+1)th disks are accessed by different heads, the heads are switched to record data on their corresponding disks.

[0010] According to a conventional disk accessing method, data can be recorded sequentially on two tracks of the m-th disk and (m+1)th disk by head switching and a track seeking. Head switching denotes a simple electrical head selection without accompanying the physical movement of a head assembly. While data is being recorded on two tracks, only a one-time track seeking is performed by the head assembly. Hence, while data is being recorded on p tracks, only p/2 times of track seeking are performed by the head assembly. Thus, the access time is reduced.

[0011] However, if disks, assembled and having information written using the off-line STW method, are accessed in the disk accessing method of FIG. 1, the time of track seeking increases, resulting in degradation in the performance of the hard disk drive. The accessing of

the disks assembled, having information written by the off-line STW method using a conventional accessing method is illustrated in FIG. 2.

[0012] Disks assembled and written using the off-line STW method have a deviation in track addresses. The deviation can be reduced through improvements in the assembly accuracy. However, substantially eliminating the deviation is almost impossible, and furthermore, the deviation magnitude may amount to several hundreds of tracks.

[0013] Referring to FIG. 2, after data is recorded on an n-th track of an m-th disk, a head switching occurs to record data on an n-th track of an (m+1)th disk. However, because a deviation exists between the tracks of the m-th and (m+1)th disks on which heads are currently positioned, the n-th track of the (m+1)th disk cannot be completely accessed by accomplishing only a head switching operation. In other words, a track seeking operation is required to position a head accurately on the n-th track of the (m+1)th disk. If the n-th track of the (m+1)th disk is accurately found, data is recorded on the found n-th track and subsequently on an (n+1)th track of the (m+1)th disk.

[0014] Thereafter, as described above, a head switching operation is performed to record data on the (n+1)th track of the m-th disk. However, as also described above, the (n+1)th track of the m-th disk cannot be completely accessed by only a head switching operation. Hence, a track seeking operation must also be performed to position the head accurately on the (n+1)th track of the m-th disk.

[0015] In summary, hard disk drives having information written using the off-line STW method must perform both a head switching operation and a track seeking operation in order to properly access disks therein. The track seeking operation typically requires about 3-4ms, which corresponds to about 1/3 of a 7,200 rpm rotation of a hard disk drive.

[0016] In contrast with hard disk drives written using the on-line STW method, hard disk drives written using the off-line STW method must additionally perform p/2 track seeking operations to compensate for the deviation between tracks while data is being recorded on p tracks. This results in degradation in the performance of the hard disk drive.

SUMMARY OF THE INVENTION

[0017] The present invention provides a head switching method improving the performance of a hard disk drive having information written using an off-line STW method.

[0018] According to an aspect of the present invention, a method of switching heads in a hard disk drive is provided. In the method, first, deviations between a reference head and each of the heads are calculated. Next, a mapping table is composed using the calculated deviations between the reference head and each of the heads and stored in a memory. Thereafter, a head in operation is switched to a head associated with a track requested to be accessed, and a deviation corresponding to the switched head, which is recorded in the mapping table, is applied to the virtual track address of the track on which the switched head is positioned, to obtain the physical track address of the track on which the switched head is positioned. The track to be accessed is accurately accessed based on the obtained physical track address.

[0019] Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and/or other aspects and advantages of the invention will become more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a diagram illustrating a conventional disk accessing method;

FIG. 2 is a diagram illustrating a process of accessing disks assembled and written using an off-line STW method according to a conventional accessing method;

FIG. 3 is a diagram illustrating a head switching method according to an aspect of the present invention;

FIG. 4 is a diagram illustrating a method of calculating an available data zone and a deviation in a head switching method according to an aspect of the present invention;

FIG. 5 is a mapping table;

FIG. 6 is a flowchart illustrating a head switching method according to an aspect of the present invention;

FIG. 7 is a perspective view of a conventional hard disk drive; and

FIG. 8 is a block diagram of a system that can control a hard disk drive to which a head switching method according to an aspect of the present invention is applied.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.

[0022] In hard disk drives having information written using an off-line STW method, the track addresses of previous and current disks on which switched previous and current heads are positioned must be the same as in hard disk drives manufactured using an on-line STW method, and thus a track seeking operation of seeking the same track on the current disk as the track on the previous disk accessed by the previous head is not required to be performed.

[0023] Accordingly, to solve the above problem, virtual addresses compensated according to a deviation between heads are used, instead of the physical addresses of the individual disks corresponding to the head positions. Data reading and writing are performed using the virtual addresses.

[0024] FIG. 3 is a diagram illustrating a head switching method according to an aspect of the present invention. In FIG. 3, the upper disk is referred to as an m-th disk, the lower disk is referred to as an (m+1)th disk, the physical track address of a track on the m-th disk on which its corresponding head is positioned is indicated by n, and the physical track address of a track on the (m+1)th disk on which its corresponding head is positioned is indicated by p. In other words, the m-th and (m+1)th disks have been assembled with a track address deviation of "a", where a=n-p.

[0025] The m-th disk is assumed as the disk that acts as a basis of address mapping (hereinafter, referred to as a reference disk). The reference disk is used in calculating track address deviations used to map the virtual track addresses of other disks. Hence, the physical track address and virtual track address of the m-th reference disk must be substantially identical.

[0026] The virtual track address of the (m+1)th disk is calculated as n', where n'=p+a, and accordingly is equal to the virtual track address n' of the m-th disk.

[0027] By using such virtual track addresses, hard disk drives manufactured using an off-line STW method can access disks in the same way as previously described in reference to FIG. 1 without a need to perform a track seeking operation as shown in FIG. 2 to compensate for a track address deviation between heads. As a result, the performance of the hard disk drives is improved.

[0028] The virtual address mapping is performed together with a head switching operation.

[0029] Since a hard disk drive typically has a plurality of disks, a mapping table having the track address deviations of individual heads for accessing corresponding disks is stored in a memory. When a head switching operation occurs, the physical track address of a new head is obtained by referring to the memory.

[0030] FIG. 4 is a diagram illustrating a method of calculating an available data zone and a deviation upon head switching according to an aspect of the present invention. FIG. 4 shows an assembly of four heads having the third head (which accesses the upper surface of the second disk from the top) serving as a reference head.

[0031] In FIG. 4, the left side refers to an outer boundary of a disk, and the right side refers to an inner boundary of the disk. In other words, FIG. 4 shows a left half of a disk. Not shown in FIG. 4 are a disk hole and the right half of the disk.

[0032] First, second, and fourth heads Hd0, Hd1, and Hd3, respectively, in FIG. 4 are assembled with track address deviations of “a”, “b”, and “c”, respectively, with respect to the third head Hd2 (reference head).

[0033] Virtual track addresses of tracks on different disks, accessed by corresponding heads, can be equalized by subtracting a track address deviation of “a” from a physical track address accessed by the first head, subtracting a track address deviation of “b” from a physical track address accessed by the second head, and subtracting a track address deviation of “c” from a physical track address accessed by the fourth head.

[0034] A mapping table having track address deviations of the individual heads is stored in a memory.

[0035] FIG. 5 shows an example of a mapping table. The mapping table of FIG. 5 records sequentially a deviation of “a” between the first head and the third head (reference head), a deviation of “b” between the second head and the third head (reference head), a deviation of “0” of the third head, and a deviation of “c” between the fourth head and the third head (reference head). A controller, included in a hard disk drive, obtains physical track addresses by referring to the mapping table stored in a memory.

[0036] The reference head of FIG. 4 has the smallest value among the deviation values recorded in the mapping table of FIG. 5.

[0037] Referring back to FIG. 4, an area within the dashed lines denotes an available data zone of a hard disk drive. Track regions to the left of the left dashed line on the first, second, and fourth disk surfaces are not used because the tracks are located outside the outer boundary of the reference disk and thus have negative virtual track addresses. Also, some disks do not have physical tracks corresponding to the virtual track addresses.

[0038] Similarly, track regions to the right of the right dashed line on the first, second, and fourth disk surfaces are not used.

[0039] When a head switching method according to an aspect the present invention is used, the storage capacity of a hard disk drive is reduced somewhat due to the non-use of tracks around the inner and outer boundaries of each disk. However, a slight loss in the storage capacity is not a major concern in large-capacity disks. Also, because the increasing multimedia environment demands a fast access time, improvements in the performance characteristics of hard disk drives is preferable to a slight loss of the storage capacity.

[0040] As shown in FIG. 4, the limit of the outer boundary of the available data zone corresponds to the first track from the outer boundary of the third reference disk surface accessed by the reference head. The limit of the inner boundary of the available data zone corresponds to the last track at the outer boundary of the second disk surface accessed by the head having the greatest deviation.

[0041] FIG. 6 is a flowchart illustrating a head switching method according to an aspect of the present invention. First, heads are positioned at arbitrary locations, and the physical track addresses of tracks accessed by the heads are obtained (S602). To be more specific, heads are positioned over the middle areas of corresponding disk surfaces, and the physical track addresses of the disk surfaces accessed by the heads are obtained.

[0042] Next (S604), a mapping table having the physical track addresses accessed by the heads is generated and stored in a memory.

[0043] In operation S606, a reference head is designated to be used for address mapping. To be more specific, a head having a physical track address whose absolute value is the smallest among the physical track addresses recorded in the mapping table is selected as the reference head.

[0044] In operation S608, the deviation of the reference head is set as a zero value by adding an identical constant to the physical track addresses accessed by the respective, individual heads.

[0045] To be more specific, the deviation of the reference head to be recorded in the mapping table is set to be zero by subtracting the physical track address accessed by the reference head from each of the physical track addresses accessed by the individual heads. The track address deviations of the heads with respect to the reference head are obtained by the above subtractions and recorded in the mapping table.

[0046] In the example, given that the physical track address accessed by the reference head (third head) is "p", if the physical track address accessed by the first head is (p+a), a track address deviation between the two heads is "a". If the physical track address accessed by the second head is (p+b), a track address deviation between the two heads is "b". If the physical track address accessed by the fourth head is (p+c), a track address deviation between the two heads is "c".

[0047] In operation S610, when a new head is requested to access a new corresponding track, a current head is switched to the new head. At this time, the track address deviation of the switched head stored in the memory is applied to the virtual track address of a track on which the switched head is positioned, thereby obtaining the physical track address of the track

on which the switched head is positioned. Using the obtained physical track address, the requested track is accessed.

[0048] Through this operation, a hard disk drive looks as if it is being accessed based on the virtual track addresses of the disks.

[0049] FIG. 7 is a perspective view of a hard disk drive 10 including at least one magnetic disk 12 rotated by a spindle motor 14. The hard disk drive 10 also includes a head 16 located close to a disk surface 18.

[0050] The head 16 can read data from, or write data to, the rotating magnetic disk 12 by detecting a magnetic field from the magnetic disk 12 and magnetizing the magnetic field. The head 16 is typically coupled to the disk surface 18. Although a single head 16 is shown in FIG. 7, the head 16 includes two separate heads: a write head magnetizing the magnetic disk 12 and a read head detecting the magnetic field of the magnetic disk 12. The read head is typically a magneto-resistive (MR) device.

[0051] The head 16 can be incorporated into a slider 20. The slider 20 produces an air bearing between the head 16 and the disk surface 18 and is coupled to a head gimbal assembly 22. The head gimbal assembly 22 is attached to an actuator arm 24 having a voice coil 26. The voice coil 26 is located close to a magnetic assembly 28 of a voice coil motor (VCM) 30. A current supplied to the voice coil 26 generates a torque for rotating the actuator arm 24 about the bearing assembly 32. The rotation of the actuator arm 24 moves the head 16 over the disk surface 18.

[0052] Data is generally stored in circular tracks 34 of the magnetic disk 12. Each of the tracks 34 generally includes a plurality of sectors. Each of the sectors includes a data field and an identification field. The identification field is comprised of gray codes which distinguish sectors from tracks (cylinders). The head 16 moves over the disk surface 18 to read data, from or write data to, the tracks. The movement of a head from one track to another track is generally referred to as a seek routine.

[0053] FIG. 8 is a block diagram of a system 40 controlling the hard disk drive 10 to which a head switching method according to an aspect of the present invention is applied. The system 40 includes a controller 42 coupled to the head 16 by a read/write (R/W) channel 44 and a pre-

amplifier 46. The controller 42 may be a digital signal processor (DSP), a microprocessor, a microcontroller, or the like.

[0054] The controller 42 supplies a control signal to the R/W channel 44 to read data from, or write data to, the magnetic disk 12. Data is typically transmitted from the R/W channel 44 to a host interface 47. The host interface 47 includes a buffer memory and a control circuit (not shown) to interact with a system such as a personal computer.

[0055] The controller 42 is also coupled to a VCM driver 48 supplying a driving current to the voice coil 26. The controller 42 supplies a control signal to the VCM driver 48 to control the excitation of the VCM 30 and the motion of the head 16.

[0056] In a reproduction mode, the R/W channel 44 modulates an analog signal read from the head 16 and amplified by the pre-amplifier 46 into a digital signal capable of being interpreted by a host computer (not shown) and outputs the digital signal to the host interface 47. Also, the R/W channel 44 receives user data from a host computer via the host interface 47, converts the user data into a write current suitable to be written to a disk, and outputs the write current to the pre-amplifier 46.

[0057] The controller 42 is coupled to a read-only memory (ROM) 50, which is a nonvolatile memory, and a random access memory (RAM) 52. The ROM 50 and the RAM 52 include command words and data that the controller 42 uses to execute a software routine. Examples of the software routine include a seek routine moving the head 16 from one track to another track and an address mapping routine for calculating virtual track addresses upon head switching. The seek routine includes a servo control routine guaranteeing a movement of a head to a correct track. The address mapping routine calculates physical track addresses by referring to a mapping table stored in the ROM 50 and the RAM 52.

[0058] The ROM 50 and the RAM 52 store a mapping table achieving an address mapping according to the present invention as shown in FIGS. 4 and 5.

[0059] The controller 42 accesses the magnetic disk 12 using physical track addresses read from the magnetic disk 12 and the mapping table stored in the ROM 50 and RAM 52. The mapping table is formed of the physical track addresses of tracks accessed by heads.

[0060] A reference head is designated to achieve track address mapping. As used herein, a head having a physical track address whose absolute value is the smallest in the mapping table is selected as the reference head.

[0061] Then, an identical constant is added to each of the deviations of the individual heads, thereby making the deviation of the reference head zero.

[0062] When a disk accessing operation is requested, the controller 42 obtains the physical track address of a disk on which a head is positioned to access, by applying the track address deviation of the disk stored in the memory to the virtual track address of the disk. Thus, a track is accessed using the obtained physical track address.

[0063] The above-described embodiments of the present invention refer to a case where disks have track address deviations between them. However, the present invention is not limited to these embodiments. For example, when disks have sector address deviations, a sector address mapping can be achieved using the above-described address mapping method.

[0064] As described above, in a head switching method according to the present invention, even when disks for a hard disk drive are formed in an off-line STW method, the individual disks can be accessed based on the same virtual track addresses. Thus, the performance of the hard disk drive is not degraded.

[0065] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in this embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.